Marginal Fit of Veneers Made From Different Lithium Disilicate CAD/CAM Materials

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Abstract:

Objective: To assess the degree of marginal adaptation of CAD/CAM milled veneers from three different lithium disilicate materials: Upcera Lithium Disilicate CAD, Rosetta SM Lithium Disilicate CAD, and Ivoclar IPS e.max CAD, with a marginal thickness of 0.3mm. **Materials and Methods:** Twenty-four laminate veneers were milled from lithium disilicate blocks (IPS e.max, Upcera, and Rosetta SM) with a marginal thickness of 0.3mm using a CAD/CAM milling machine (Sirona Cerec MCXL), each group of materials consists of 8 veneers and were cemented to duplicated epoxy dies then a digital microscope was used to assess the marginal adaptation. **Results:** For cervical surfaces, IPS e.max showed a significantly higher value than other materials ($p<0.001$). For proximal (1), Upcera material showed a significantly higher value than other materials ($p<0.001$). For all other surfaces and the total averages for each sample, the difference was not statistically significant between the three materials ($p>0.05$). **Conclusions:** Within the limitations of this in vitro study, the following conclusion was drawn: The overall marginal gap values of laminates fabricated from IPS e.max, Upcera, and Rosetta SM lithium disilicate CAD blocks are comparable to each other and are considered to be clinically acceptable.

Introduction:

The last decades have witnessed rapid progressive elaborations of many conservative and esthetic approaches that treat variable dental problems. Ceramic laminate veneers have captured the interest of worldwide dentists and patients as a treatment method that satisfies increasing esthetic and mechanical demands.[1] Hence, a variety of new dental materials and processing technologies are available to achieve such demands and requirements of laminate veneers.[2-4]

A variety of metal-free dental ceramic materials are available bringing out excellent esthetical, mechanical, and biological outcomes. They can be classified according to their microstructure into glass ceramics, particle-filled glasses, and polycrystalline.[5] Among the particle-filled glass ceramics lies the dental lithium disilicate ceramics. They have revolutionized all-ceramic restorations by enhancing the properties of glass-based ceramics in dentistry.[6] Lithium disilicate ceramics are made of a glassy matrix of silica through which lithium oxide crystals are dispersed. The crystals are oriented in an interlocking manner that prevents cracks propagation and provides flexural strengths of up to 440 MPa.[7] Thus the presence of lithium disilicate crystals in glass ceramics enhanced mechanical properties and durability over conventional dental ceramics.[8]

Lithium disilicate restorations are biologically compatible with surrounding periodontal tissues.[9]

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Moreover, their excellent optical properties enhanced patients' esthetics and self-esteem.[10]

Nowadays computer-aided design and computer-aided manufacturing (CAD/CAM) have been successfully widely used in dentistry, as CAD/CAM technology offers the rapid making of chair side time esthetically and mechanically pleasing restorations.[11,12] The advantages of productivity increase in laboratory processes, time-saving, quality control, and the elaboration of highly uniform and good quality restorations made it ranked high among the recent dental technologies.[13-15]

CAD/CAM restorations can be fabricated either by subtractive or additive techniques. In the subtractive technique, the restoration design is made followed by data processing by automatic calculations.[14]

Of the most critical factors that play an important role in determining the clinical success and durability of the restoration is its marginal fit, as any discrepancy may lead to plaque accumulation, recurrent caries, and periodontal breakdown thus failure of the restoration.[16]

Different methods are available for the evaluation of dental restoration marginal adaptation among them; dental scanning electron microscopy (stereomicroscope)[17], optical microscopy[18], and micro-computed tomography (m-CT).[19]

Several manufacturers are now introducing many lithium disilicate glass-ceramic materials. Therefore, the objective of this in-vitro study is to evaluate and compare lithium disilicate glass-ceramic materials fabricated by different manufacturers that are CAD/CAM milled for the construction of laminate

Table 1: Materials used in this study

Brand Name	Material description	Manufacturer	Composition	LOT number
IPS e.max blocks Block size #14	Lithium disilicate	Ivoclar Vivadent, Schaan, Liechtenstein	Components: SiO2 Additional components: Li2O, K2O, MgO, Al2O3, P2O5 and other oxides	R24003
Upcera lithium disilicate blocks Block size #14	Lithium disilicate	Shenzhen Upcera Dental Technology Co, China	SiO_2: 58.5%~72.5% Li2O: 13%~15% K2O: 3%~5% Other oxides: 7.5%~25%	E415395
Rosetta SM blocks Block size #14	Lithium disilicate	Hass, Gangneung,. Korea	SiO2 (56–64%), Li2O (15–21%), ZrO2 (8–12%), and other minor oxides	BF03EF1410
Choice 2 Shade: translucent	Veneer resin Cement	Bisco Inc., Schaumburg, IL, USA	BIS-GMA, TEG DMA, UDMA	0900011425
Itena DentoBond Porcelain etch	Hydrofluoric acid gel	Itena, France	Hydrofluohydric acid (8%) Aqua 90.5% Xanthan gum 1.5%	DBPF-2.5
Itena DentoBond Porcelain	Silane liquid	Itena, France	Ethyl alcohol 97% Glycidoxypropyltri-methoxysilane 3%	DBPF-2.5
Elite HD+	Addition Silicon Impression material putty and light body	Zhermack dental, Italy	Polymethyl hydrogen siloxane, other siloxane prepolymers, and fillers. Catalyst:divinylpolysiloxane, fillers, platinum salt, palladium and more	C203010
Kemapoxy cast	Clear Epoxy Casting Resin	CMB, Egypt	Epoxy Resin	04-0301226001
Voco structure 2 SC	Provisional crowns and bridges material	Germany	Bis-Acrylic Composite	0938052

veneers of 0.3mm thickness in terms of marginal fit. The null hypothesis is that the type of lithium disilicate material doesn't significantly affect the marginal adaptation of veneers.

Materials and Methods:

Materials:

Materials used in this in vitro study are summarized in Table 1.
The scanner that was used in this study:CEREC Omnicam scanner (a Dentsply Sirona product).
The milling machine that was used in this study: InLab MCXL, a four-axes milling machine.
Twenty-four laminate veneers were milled from lithium disilicate CAD blocks (IPS e.max blocks, Upcera blocks, and Rosetta SM blocks) with a thickness of 0.3mm using a CAD/CAM milling machine (Sirona Cerec MCXL) and cemented to duplicated epoxy dies using translucent light-polymerized resin cement (Choice 2, Bisco Inc., Schaumburg, IL, USA), then a digital microscope was used to evaluate the marginal adaptation.
Sample Grouping: In this in vitro study, twenty-four specimens were divided into three groups (n=8) according to their material type. All laminate veneers were milled with the same thickness of 0.3mm.

Group E: Laminate veneers were fabricated from IPS e.max CAD blocks.
Group U: Laminate veneers were fabricated from Upcera CAD blocks.

Group R: Laminate veneers were fabricated from Rosetta SM CAD blocks.

Study Methodology: 1- Model preparation:
A typodont (NISSIN dental cast, Japan) was used for the preparation of the upper left central incisor (tooth#21) to receive laminate veneers of 0.3mm chamfer finish line thickness.
A putty index made from vinyl polysiloxane impression material was made to be used for checking the amount of preparation by measuring the acrylic

veneer's marginal thickness as previously made by El-Mahdy et al.(2020).[20]

The depth of facial reduction was 0.3mm for tooth #21. The preparation was not extended to the interproximal contact with no incisal or palatal extensions. A modified dental surveyor (Parabur, Bego, Germany) was used to standardize the preparation as done in a previous study by Abdullah et al.(2017).[21] Self-limiting depth cutter stone of depth 0.3mm (Brasseler, USA, 834-31-016) was used. A pencil was used to mark the depth cuts. Then a tapered with rounded end stone (TR #12) (Brasseler, USA, KS1;35005-31-52-012) was used to refine the preparation. A temporary veneer was fabricated from BIS-acrylic material (Voco structure 2 SC) using the silicone index and a caliper was used to measure the acrylic veneer's marginal thickness to ensure the preparation depth of 0.3mm chamfer finish line thickness.

For further confirmation of the preparation depth, the silicone index was sliced with bard parker #11 and used for checking the even amount of preparation.

2-Epoxy resin dies fabrication: Twenty-four impressions were made for the typodont using a stock tray with Elite HD+ addition silicone impression material. With the one-step impression technique, a light impression material is injected around the prepared teeth, and then the putty impression material is immediately placed over it and the impression materials polymerize simultaneously. A non-shrink epoxy resin material (Kemapoxy Cast) was used to pour the impressions. The two components of epoxy (the Liquid resin A structure and the hardener B structure) were mixed with a ratio of 3A:1B by weight according to the manufacturer's instructions for 3 minutes on a vibrator to avoid air bubbles entrapments.

After 24 hours the epoxy resin was set. The epoxy dies were separated from the impressions and subsequently left for 7 days in a cool dry place to ensure maximum hardness. Each die was marked with its serial number for easy identification.

3- Administration, scanning, and designing:
A. Administration: The software Cerec Premium 4.4.4 was opened to start scanning and designing. On the administration page of the software, the laminate veneer restoration was selected. The milling machine Cerec MCXL and the block material were chosen. Then proceeding to the scan page to start scanning.
B. Scanning: Omnicam intraoral scanner was used. The typodont tooth was fixed in the cast and placed on a stable object and then scanned by continuous imaging, where consecutive data acquisition generates a 3D model, whereas imaging is a single image acquisition.
C. Designing: Using Cerec premium 4.4.4 software, the following steps were done by order:
-Setting the model axis for the abutment.
-Editing the jawline of the model.
-Drawing tooth restoration margin.
-Defining tooth insertion axis.
-Setting restoration parameter for 0.3 mm laminate veneer thickness.
-Restoration proposal editing.

4- Milling the restoration: Using Cerec MCXL milling machine, block size C14 was selected, the device was selected, the veneer was positioned in the block and a sprue was attached to the middle of the labial surface to avoid any distortion at the margins during cutting of the sprue. The milling machine was started up by pressing the on-off button. The block was inserted into the holder and the screw was tightened. The start button was pressed, and the instruments were checked. Then, the restoration production was started achieving laminate veneers made of each lithium disilicate material. After finishing the milling, a fine tapered diamond stone with a straight handpiece was used to separate the veneers. The veneers were checked for any defects as any defective veneer was planned to be excluded and remade.

5- Finishing, polishing, crystallization, and glazing of veneers: Each veneer was finished using a tapered with a rounded end stone and then polished using a polishing system (Celtra twis tec, DeguDent Gmbh, Germany). The green-coded polishing stone then the yellow-coded stone and finally the grey-coded one were used to reach the maximum surface finish.

Then, IPS e.max CAD crystal/glaze paste was applied evenly on the outer surfaces. Veneers were then secured on the firing tray and placed into the Programat P310 ceramic furnace from Ivoclar Vivadent for the glazing and crystallization cycle to start.

Veneers were removed from the furnace and allowed to cool to room temperature, then cleaned in an ultrasonic water bath to remove any residues and checked again for any minor adjustments.

Then, a digital caliper was used to ensure that finishing did not affect the veneers' marginal thickness, Figure 1.

6- Samples cementation: All the samples were cleaned in an ultrasonic cleaning device using distilled water for one minute. All the veneers were treated with hydrofluoric acid etch gel for 20 seconds and then rinsed with air water oil-free spray. After etching and rinsing, the ceramic silane primer was added for 60 seconds and then air-dried.
The tack and wave technique was used to cement the veneers to their corresponding dies. The resin cement was applied to the surface of the epoxy dies and each veneer was seated on its corresponding epoxy die.
Finger steady pressure was applied for veneers seating. The samples were initially cured for 2 seconds, thus allowing the cement to establish a semi-gel state which allows the veneers to be initially seated without any drifting or falling off. This also allowed any excess cement to be easily peeled off from the gingival, interproximal, and incisal margins before the final polymerization using a sharp bard parker blade #11. The final curing was made for another 40 seconds in each margin.

Figure 1: Digital Micrometer is used for checking veneer's marginal thickness of 0.3mm.

7- Measuring marginal adaptation: Vertical marginal adaptation of all cemented veneers was evaluated using a digital microscope.

Shots of the margins were taken for each veneer using a hand-held digital microscope with a built-in camera fitted on a precision microscopic stand connected to an IBM-compatible personal computer using a fixed magnification of 50X, Figure 2.

Then morphometric measurements were done on an IBM-compatible personal computer equipped with the Image-tool software (Image J 1.49d, National Institute of Health, USA) which was used for image analysis. Within the Image J software, all limits, sizes, frames, and parameters are expressed in pixels. System calibrations were done to convert the pixels into absolute real-world units. The calibrations were done by comparing an object of a known size (a ruler in this study) with a scale generated by the Image J software. The vertical marginal gaps were measured for each shot at 5 equidistant landmarks along the gingival, incisal, mesial, and distal margins of veneers. Measurement at each point was standardized by markings on the die. The data obtained were collected, tabulated, and then subjected to statistical analysis. Figure 3 is a shot of the gingival margin under the stereomicroscope of IPS e.max veneer made of 0.3mm marginal thickness produced by MCXL milling machine.

Statistical analysis: Numerical data were explored for normality by checking the data distribution using Shapiro-Wilk tests. Data showed parametric distribution so; they were represented by mean and standard deviation (SD) values. Two-way ANCOVA followed by Bonferroni post hoc test was used to study the effect of different tested variables and their interaction while adjusting for measurements. The significance level was set at $p \leq 0.05$ within all tests. Statistical analysis was performed with R statistical analysis software version 4.1.3 for Windows.

Figure 2: Digital microscope mounted on a precision stand.

Results:

Mean and standard deviation (SD) values of marginal

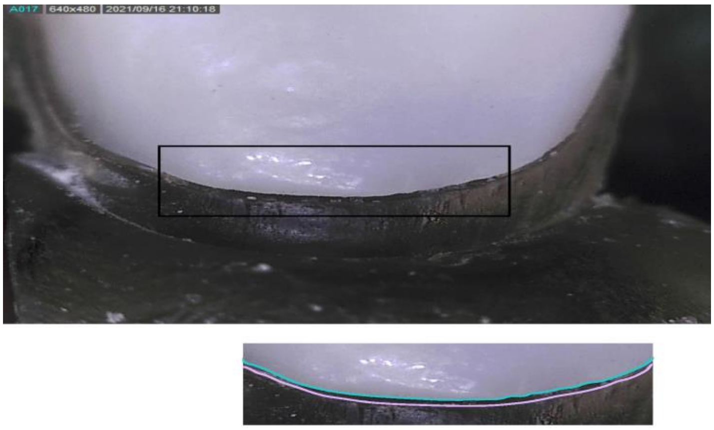

Figure 3: The gingival margin under stereomicroscope of IPS e.max veneer made of 0.3mm marginal thickness produced by MCXL milling machine.

fit (µm) for different materials were presented in Table 2 and Figure 4.

For the cervical surface, there was a significant difference between different materials ($p=0.006$) and post hoc pairwise comparisons showed IPS e.max material to have a significantly higher value than the other materials ($p<0.001$).

For proximal (1), the difference was also statistically significant ($p=0.033$), and post hoc pairwise comparisons showed Upcera material to have a significantly higher value than the other materials ($p<0.001$).

For other surfaces, the difference was not statistically significant ($p>0.05$).

Results Summary:

1. IPS e.max lithium disilicate laminate veneers showed a significantly higher marginal gap value than other materials only cervically.

Table 2: Mean ± standard deviation (SD) of marginal fit (µm) for different materials

Surface	Marginal fit (µm) (mean±SD)			p-value
	Upcera	Rosetta	Emax	
Cervical	95.62±1.58^{B}	96.02±1.59^{B}	98.09±1.59^{A}	**0.006***
Incisal	104.71±4.32^{A}	106.07±4.81^{A}	107.89±4.96^{A}	**0.337ns**
Proximal1	89.52±2.68^{A}	86.11±2.72^{B}	88.74±2.73^{AB}	**0.033***
Proximal2	84.07±5.16^{A}	83.49±4.98^{A}	88.56±5.16^{A}	**0.100ns**
Average	94.47±1.31^{A}	93.91±1.21^{A}	94.57±1.16^{A}	**0.458ns**

Means with different superscript letters are statistically significantly different *; significant ($p \leq 0.05$) ns; non-significant ($p>0.05$).

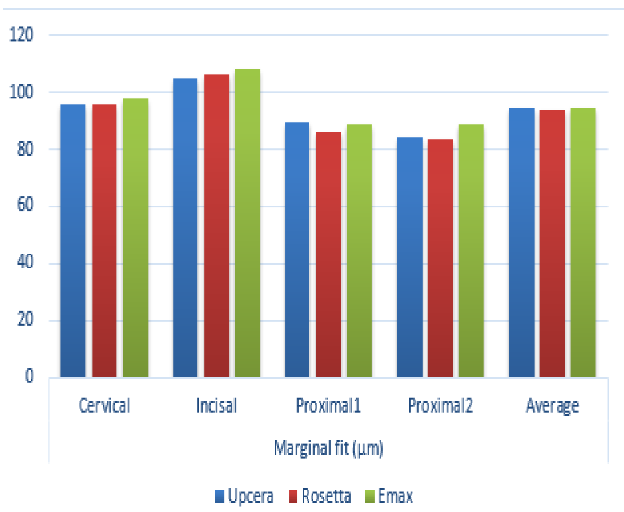

Figure 4: Bar chart showing average marginal fit(µm) for different materials.

2. Upcera lithium disilicate laminate veneers showed a significantly higher marginal gap value than IPS e.max and Rosetta SM only in the proximal 1 surface.
3. For all other surfaces, and the total averages for each group of materials, the difference was not statistically significant between the three materials.

Discussion:

Nowadays ceramic laminate veneers are considered to be one of the most frequently used treatment options for high esthetical and mechanical expectations.[1]

The clinical long-term success of dental restorations is determined by many factors such as the restoration's marginal fit, as any discrepancy may lead to plaque accumulation, recurrent caries, periodontal problems, and subsequently the failure of the restoration.[16] That's why marginal fit was chosen to be tested in our study.

Several manufacturers are nowadays introducing many lithium disilicate glass-ceramic materials. The objective of this study is to assess the marginal fit of laminate veneers made from lithium disilicate glass ceramics fabricated by different manufacturers (IPS e.max CAD blocks with the Rosetta SM blocks and Upcera lithium disilicate CAD blocks).

In this research, a typodont model (NISSIN Dental Model, Kyoto Japan) was used instead of the natural teeth despite the benefit of the natural teeth regarding stimulating clinical conditions. However, using a typodont model would guarantee standardization through caries-free and restoration-free teeth which might affect the measurements of the study.[22] One more reason for using epoxy resin dies in this study is that the natural teeth may vary in age, time storage, and individual structure as reported by Hamza and Sherif.[23]

Since the maxillary central incisors are the most common teeth to be restored with ceramic laminate veneers and because they have a significantly higher survival rate than the mandibular ones, they were chosen to be prepared for laminate veneers in the current study.[22] Moreover, El-Mahdy et al.[20] used the maxillary central incisors in their study and they stated that the large width and fewer curvatures of the maxillary central incisors will provide a good surface for testing.

Literature showed a variety of preparation designs and thicknesses of laminate veneers, however; all new trends are going towards minimally invasive techniques. This will offer less tooth structure removal and enough enamel thickness for good bonding between the tooth and restoration. However, it was noted that excessively decreasing the preparation depth may lead to marginal chipping of the restoration during the milling step and so the loss of the marginal adaptation of the restoration to the tooth, this amplifies the use of new materials that can be milled into thin sections without loss of marginal adaptation.[24,25] In this study, 0.3mm thickness was selected to evaluate the marginal fit of laminate veneers milled in thin thickness.

The preparation was done without overlapping the incisal edge and was not extended beyond the contact area of each tooth, thus allowing easy capturing and measuring of the gap between the restoration and the tooth.

To standardize the preparation depth, a silicone putty index was made for the tooth before the preparation and used to re-check the preparation amount by making an acrylic veneer from it. The acrylic veneer's marginal thickness was checked using a caliper. Depth cutter stone was also used to make depth-oriented grooves that acted as a guide during reduction. A dental surveyor was used during preparation.

As done by Aldafeeri et al.(2019)[26], the model was scanned after preparation using an intraoral scanner (Omnicam, Sirona, Germany), and the STL data was exported for a free choice of design and production. The restoration design of the laminate veneers was milled using the Cerec MCXL Milling Machine.

The designed veneers were fabricated with the same thickness as the preparation depth, this is checked by using a digital caliper. Milling laminate veneers of thicker thicknesses than the preparation would lead to less pleasing esthetics due to over-contouring of the restoration as well as periodontal issues.[27]

In the present study, the assessment of the fit of the laminate veneers was done after the cementation of veneers to their corresponding epoxy dies to simulate the actual clinical fit intraorally as a higher marginal misfit was observed with the cementation procedure as a result of the viscosity of the cement.[17]

In addition, Borges et al.[28] concluded that the cementation procedure may play a role in the marginal discrepancy due to the chipping of the thin ceramic at the margins of the veneer as a result of the seating pressure. Light-cured veneer cement was used for the cementation procedure to allow better control during the seating of the laminate veneers compared to other types of cement.[29] Another reason, for using light-cured veneer cement is its color stability since dual-cured and chemically cured resin cements are subjected to color changes. The tack and wave technique was used during cementation, this technique allows excess cement to be easily peeled off from the margins and hence good and easy margin detection under the microscope.
The null hypothesis of neither the type of lithium disilicate material nor the laminate veneer thin margin thickness affects its marginal adaptation has been proven to be accepted.

Vertical marginal adaptation of all cemented laminated veneers was evaluated using a digital microscope.

Shots of margins were taken for each veneer using a hand-held digital microscope with a built-in camera fitted on a precision microscopic stand that was connected to an IBM-compatible personal computer using a fixed magnification of 50X power. This method is an easy and non-destructive measuring way that was recommended by many researchers and authors.[30]

Results showed that IPS e.max had a significantly higher value than other materials only in cervical margins, and Upcera material had a significantly higher value than other materials only in proximal 1 margins, this might be due to slight minor movements induced during veneers seating applied by finger pressure.

While the total averages for all surfaces were not statistically significant for the three lithium disilicate materials, this might be due to the almost similar microstructure and mechanical properties of the three materials.

A study made by Suk-Ho Kang et al.[31] to observe the crystalline structures of IPS e.max CAD and Rosetta SM CAD materials. They had a similar crystalline pattern and molecular composition which might explain the absence of significant differences in their restorations' marginal adaptation.

Values reported in the literature as acceptable marginal adaptation showed variations according to the type of restoration and the researcher. Taking these factors into clinical consideration, a marginal gap up to 145 μm could be acceptable.[32] In the present study, the marginal gap values were recorded to be between 83 and 107 μm which is clinically acceptable.

Conclusion:

Within the limitations of this in vitro study, the following conclusions were drawn:

The overall marginal gap of laminates fabricated from IPS e.max, Upcera, and Rosetta SM lithium disilicate CAD blocks are comparable to each other and are considered to be clinically acceptable.

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